# ILLUMINATING GAS IN ITS RELATIONS TO HEALTH.

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**A brief description of the principles of gas manufacture.**
**(*a*.) Coal gas.**
**(*b*.) Water gas.**
**(*c*.) Petroleum gas.**
**Noxious constituents of the various kinds of illuminating gas.**
**Injurious or offensive products evolved during the manufacture, purification, and combustion of the gas.**

In the limited time allotted, it will be impossible to give more than a brief description of the processes in the manufacture of illuminating gas, and only those will be referred to which have a bearing upon the sanitary questions before us.

Illuminating gas is made almost exclusively from bituminous coal. For this purpose, bituminous coal is distilled in a closed retort, and evolves certain gases and vapors, some of which are combustible, and some, like steam, are condensable, a residue of coke being left behind. This process is the most important of the operations in making coal gas, and also appears to have the greatest influence upon the health of those employed in the works. But, in addition to this, it is necessary, before the gas is delivered to the holder, to remove from it those vapors which can be condensed, such as tar, water, etc., and also those non-condensable gases, which either diminish largely the illuminating power, if left in the gas, such as carbonic acid, or which, when the gas is burned, give rise to products of combustion which are injurious, such as sulphuretted hydrogen and ammonia. The removal of these necessitates two other operations, — condensation and purification, the latter of which may or may not prove a nuisance to the whole neighborhood of the works, according as it is done properly or not.

First, as to the distillation of the coal. This is performed in iron or clay retorts, three, five, six, or seven of which, according to circumstances, are heated with one fire of coke to a high temperature. From 160 to 200 lbs.

of coal are usually introduced into the retort at a time, the lids closed, and the operation allowed to continue uninterruptedly for four or four and a half hours. At the expiration of this time the retorts are opened, the hot coke raked out, and a fresh charge of coal introduced. The coke is wheeled to some convenient place and quenched with water. The men engaged in tending the retorts are very liable to become affected with more or less severe affections of the respiratory organs. Dr. Petersen, city physician of Copenhagen, has published the results of his researches respecting the maladies of the employees at the gas-works of that city: "Of 338 cases treated, 200 were among the retort tenders; 266 of the cases were non-surgical, and of these ninety-six were of chronic or severe affections of the respiratory organs, fifty of catarrhal dyspepsia, twenty-eight of general debility, with fever, and twenty-six of rheumatic affections. The more serious respiratory affections in gas employees generally arise from prolonged catarrh, and, for the most part, consist of symptoms of bronchitis and phthisis, and of these cases, eleven per cent. were of persons possessing originally strong constitutions." There are two causes which contribute to this result. First, the exposure to very great variations of temperature. The top of the retort-house is always open, in order to permit the escape of the products of combustion from the fires, and in most places the sides of the retort-house are entirely open, or contain large doors, at short distances from each other, through which the coal may be brought, and the hot coke wheeled away. This condition of things occasions, necessarily, draughts, and excessive changes of temperature in the winter season. In addition to this, it appears probable that the coal and coke dust add somewhat to the cause of the catarrhal affections of the respiratory organs.

The gas passes from the retort, through the hydraulic main to the condenser, thence to the washers, where most of the ammonia is removed, and finally to the purifiers, where those noxious substances, not removed by the condenser and washer, are taken away from it. These substances are chiefly carbonic acid and sulphuretted hydrogen. The objection to carbonic acid in gas is, that it lowers the illuminating power very greatly. The sulphuretted hydrogen and other gaseous sulphur compounds are injurious, by giving rise in burning to sulphurous and sulphuric acids which may injure delicate structures, such as books, gilding, silks, etc., that may be exposed to the air of a room in which gas is burned. There is quite a difference of opinion among scientific men as to the injurious effects of sulphur in illuminating gas, but the weight of evidence appears to me to be greatly in favor of the statements of those who maintain that it is very injurious, and should be removed from gas as thoroughly as possible. Where large quantities of impure gas are burned, it causes a rapid destruction of textile fabrics with a very acid condition of them. This was especially noticed in the large public libraries in London many years ago, the covers of many of the books in the Athenæum Club-house, the College of Surgeons, and elsewhere, becoming destroyed by the sulphuric acid from the burning gas. The amount of this acid was so great, that it could be easily tasted by applying the exposed portions of the books to the tongue. Plants are quickly killed by the products of

burning gas, since they are peculiarly susceptible of injury from the presence of sulphurous acid in the air; according to Drs. Christison and Farmer, as little as one part in 10,000 of air will kill plants in less than twenty-four hours. And you cannot use gas in a conservatory, either for heating or for illuminating purposes, unless the products of combustion are entirely removed.

According to Mr. Chas. Heisch, Superintending Gas Examiner to the Corporation of the City of London, when sulphur is burned in a moist atmosphere (as is always the case with illuminating gas), the amount of sulphurous acid formed is quite insignificant, nearly all of the sulphur being converted into sulphuric acid, which is a vapor readily condensed on the walls of, and articles contained in, a room. Each grain of sulphur, in burning as it does in gas, gives rise to the production of just over three grains of sulphuric acid; one hundred cubic feet of gas, if they contain thirty grains of sulphur (a very common amount), would in burning produce ninety grains of sulphuric acid; and three burners, each burning four feet per hour, would produce between three and four grains of sulphuric acid per hour, or about twenty grains in six hours, which would in great part be condensed on the contents of the room in which the gas is burned. One very striking instance, in proof of the above, is given: "Some years since gas was introduced at the Royal Observatory in place of camphene lamps, for the photographic registration of magnetic variations, etc. In a very short time the surface of every reflector was destroyed, and the draw tubes of the telescopes quite corroded. It was found necessary to place a tube over each burner, and to connect all of these with a central chimney, in which a strong draught was maintained to carry off the products of combustion. These tubes were, for cheapness, made of zinc. In a few days all of the lamps were found extinguished by a crystalline substance, which dropped on the burners from the tubes. This proved to be sulphate of zinc. To prevent this, a contrivance was resorted to, by which the condensed matter was run into a vessel at the side of the chimney, and in one of these vessels there was collected in six weeks, from a burner consuming only about a half foot per hour, three-quarters of a pound of sulphate of zinc."[1]

It is impossible to remove the sulphur entirely from gas, but nearly all of it may be got rid of. The English law requires that gas shall be absolutely free from sulphuretted hydrogen, and that the amount of sulphur in other forms of combination shall not exceed twenty grains (or in some works twenty-five grains) per one hundred cubic feet.

To remove the sulphuretted hydrogen, carbonic acid, etc., several methods are in use, the material used being lime and oxide of iron. Lime is used both in the wet and dry way. The wet lime process consists in passing the gas through milk of lime. This effectually removes the carbonic acid, uniting with it to form chalk, and takes away most of the sulphur compounds by uniting with them to form calcic sulphide or sulpho-carbonate. The wet lime is, however, very objectionable on account of the foul

[1] *London Journal of Gas Lighting*, December 29, 1874, page 856.

odor evolved from it when removed from the purifier, so that exclusive purification by wet lime has been generally abandoned. The dry lime process consists in passing the gas through moistened slaked lime placed upon trays. This is about as effective as the wet lime process, and is generally used in this country, but has been largely complained of as a nuisance where the works are situated in thickly settled districts, on account of the noxious and offensive odors evolved from the lime when removed from the trays, so that in New York city the companies have been compelled by the Board of Health either to resort to special apparatus for ventilating the lime and consuming these gases, or to use the iron oxide mixtures for purification. In this city (Boston) a combination of the wet and dry lime processes is used. The wet lime through which the gas is first passed, and which retains most of the foul gases, is drawn from the purifier through a series of boxes and settling basins before the water finally comes into contact with the air when there is but little stench arising from it; and the dry lime, when spent and removed from the purifiers, has no unpleasant odor.

The iron process never creates a nuisance. This consists in passing the gas through some mixture containing sesquihydrate of iron. The great advantage of this is its cheapness, since the same mixture may be used over and over again. The sulphuretted hydrogen in the gas reduces the sesquihydrate of iron, to form water, sulphur, and hydrated sulphide of iron, which last, on exposure to the air, is changed again to sesquihydrate of iron, and more sulphur is set free. This process is adopted very extensively in the European works on account of its economy.

The difference between the action of the lime and that of the iron mixtures appears to be chiefly that, while the lime removes from the gas the impurities which it contains, perhaps better than the iron mixtures, yet, upon the opening of the purifiers, it permits the offensive and noxious sulphurous gases, like sulphide of ammonium, to escape into the atmosphere, become diffused throughout the neighborhood, and act as a nuisance, much more readily than the iron purifier does, which fixes the sulphur by combining with it. So that, where works are situated in thickly settled districts, the principal portion of the noxious constituents of the gas should be removed by wet lime before the gas passes through the dry lime, as in this city, and the "blue billy," as the wet lime residue is called, disposed of in such a manner as not to become a nuisance; or the dry lime should be thoroughly ventilated before the purifying boxes are opened, or recourse should be had to the iron mixtures.

Gas thus made consists chiefly of hydrogen (40–50%), marsh gas (35–45%), carbonic oxide ($4\frac{1}{2}$–$7\frac{1}{2}$%), olefiant gas and other hydrocarbons (4–8%), and usually very small amounts of carbonic acid and air. Cannel gas has about the same composition, the proportion of the hydrogen, marsh gas, and olefiant gas being a little different.

Gas made from *petroleum* or *naphtha* need not occupy our attention, although it is made quite extensively in many of our large cities for enriching purposes, since when made from Pennsylvania petroleum it contains no sulphur or ammonia, and requires no purification; and I have heard it

stated by those familiar with it that the *pure* petroleum or naphtha gas can be inhaled with as much impunity as nitrous oxide, the symptoms produced being quite similar. By naphtha gas, I do not mean such gas as is made in gasoline machines, but gas made by decomposing the naphtha in heated retorts.

*Water Gas.* — There is still another variety of gas which is becoming quite rapidly introduced into many smaller towns, and which requires our careful consideration. I refer to the so-called water gas. The theory of the manufacture of this gas differs entirely from that of coal or naphtha gas. It depends, first, upon the production of a non-illuminating gas from steam; and, secondly, upon the manufacture of petroleum, naphtha, or cannel gas, for the purpose of furnishing the luminants. The great advantage of this process is, that very large volumes of non-luminous combustible gas can be made very cheaply. This is done by passing steam over incandescent carbon, which has a very powerful attraction for oxygen, abstracts it from the steam, and unites with it to form at first a mixture of hydrogen and carbonic acid. The carbonic acid is, on passing through another layer of coal, deprived of one half of its oxygen, and carbonic oxide is formed. Thus we have as the result, if the process has been properly conducted, a mixture of hydrogen and carbonic oxide, both of which gases are combustible, but burn with a colorless flame.

In making water gas, anthracite, not bituminous coal, is used, and great care is necessary to keep the temperature up to a white heat, since if it falls too low, a large proportion of carbonic acid is formed, which diminishes the yield of the finished gas, since it must be removed by purification, or if it is not removed, it injures the illuminating power very much. Anthracite coal contains sulphur and yields ammonia when distilled, so that purification is as necessary in the case of water gas as of coal gas. Water gas as thus made contains as a rule about forty to fifty per cent. of hydrogen, thirty to forty per cent. of carbonic oxide, and about ten per cent. of petroleum or naphtha gas.

Strenuous efforts are of course being made by the owners of the various patent processes for making water gas to have it introduced into our large cities, and they advance as one of their strong arguments, the fact that the non-luminous gas alone can be distributed for heating purposes at a cost of only a few cents per thousand feet. But the distribution of this mixture of hydrogen and carbonic oxide alone for heating purposes should be opposed in every possible way, for the reason that, since it is comparatively devoid of odor, its escape from pipes and diffusion through the air of an inhabited room in dangerous amount could not be detected. This mixture contains nearly fifty per cent. of carbonic oxide, which is one of the most active of poisons, producing when inhaled speedy death, and according to Leblanc, "one vol. of it diffused through 100 vols. of air totally unfits it to sustain life; and it appears that the lamentable accidents which too frequently occur from burning charcoal or coke in braziers and chafing-dishes in close rooms, result from the poisonous effects of the small quantity of carbonic oxide which is produced and escapes combustion, since the amount of carbonic

acid thus diffused through the air is not sufficient in many cases to account for the fatal result."[1]

When it was proposed to supply the *Invalides* in Paris with water gas, a commission was appointed, consisting of Messrs. Dumas, Chevreul, and Regnault, eminent chemists, to investigate it. They found that it contained from thirty to forty per cent. of carbonic oxide, and reported "that it would be dangerous to the occupants of the institution to introduce, even by way of experiment, gas obtained from the decomposition of water by the *Kirkham* process."[2] This gas was the odorless carbonic oxide and hydrogen mixture.

H. Letheby says,[3] "Seligue, in 1840, obtained permission to use the gas in the towns of Dijon, Strasburg, Antwerp, and two of the faubourgs of Paris, and Lyons. At Strasburg an accident occurred which put a stop to its use. The gas escaped from the pipes into a baker's shop, and was fatal to several persons; and not long after an aeronaut, named Delcourt, incautiously used the gas for inflating his balloon. He became insensible in the car, and those who approached to render him assistance fainted and fell likewise. The use of the gas has therefore been interdicted on the continent."

It is a somewhat significant fact that, although the manufacture of water gas for illuminating purposes on a large scale has been subjected to investigation, experiment, and trial for more than twenty years in Europe, none of the large European companies have adopted it. It does appear, however, to have been much more successful in this country than in Europe, probably on account of the introduction of petroleum, which affords a cheap and adequate means of enriching it with luminants. Formerly the illuminating power was obtained by introducing into the non-luminous flame, metallic platinum, or by mixing the water gas with rich gas obtained from peat, resin, or some other carboniferous material.

The above remarks in regard to the danger of water gas apply especially, if not only, to the odorless non-luminous gas. The addition to it of petroleum gas very greatly diminishes the danger by imparting to it a very powerful odor, and also dilutes slightly the carbonic oxide. No accidents have, so far as I have been informed, yet occurred in those works in this country where water gas has been manufactured. It is especially against the comparatively odorless gas for heating purposes that we should be upon our guard.

Experimentally, carbonic oxide can be removed by heating to a high temperature in contact with an excess of steam; but that this is accomplished in any of the processes used for making water gas upon a large scale, I am unable to say. This is more likely to be accomplished in what is known as the "Lowe" process (Manayunk) than in any of the others, since an excess of steam passes with the gas from the furnace or generator through a chamber filled with white hot fire-brick called a super-heater or fixer. The carbonic oxide is not destroyed in the "Harkness" process (which was in

[1] Bloxam's *Chemistry*, page 118.

[2] *London Journal of Gas Lighting*, June 10, 1856.

[3] *London Journal of Gas Lighting*, May 20, 1862.

use in New London, Conn., but which has been discontinued recently on account of the high price of petroleum), as more than forty per cent. was found by eudiometric analysis. About thirty per cent. of carbonic oxide was found in the pure water gas made by the "Gwynne-Harris" process, which is now in use in Poughkeepsie, N. Y. Ordinary coal gas has, as I have already mentioned, usually from five to seven per cent. of carbonic oxide.

From a sanitary point of view, therefore, the principal points to be borne in mind, and to be obviated if possible, are: (1) the exposure of the workmen to excessive changes of temperature and violent draughts of air while heated; (2) to remove from the gas the noxious impurities and those which on burning give rise to noxious products of combustion as completely and thoroughly as possible, and at the same time dispose of the purifying material in such a manner as not to create a nuisance; and (3) to prevent the introduction of the dangerous inodorous mixture of hydrogen and carbonic oxide for heating purposes. I have dwelt somewhat at length upon this last subject, because the manufacture of water gas appears to be attracting the serious attention of many gas engineers at the present time, and works are now in operation manufacturing from 50,000 to 150,000 cubic feet per day each. The mixture of water gas with cannel or petroleum gas appears, however, practically to be but little if any more dangerous than common coal gas.